Geochemical behavior of heavy metals during wastewater treatment in Chingola Stream of the Zambia Copperbelt

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The study focuses on an area at a copper mine in Chingola town of the Zambian Copperbelt where wastewater containing heavy metals (Cu-Co-Mn) at variable pH (3.5-6.5) mixes with a nearby municipal wastewater in Chingola Stream. The metal concentration of discharge is below the regulation limit because lime treatment has been conducted in the stream. However, remaining volume of ponds for sludge produced by lime treatment was limited. The objective of the study was therefore to understand the geochemical behavior of the metals for the optimization of wastewater treatment. Representative water and soil samples were obtained along the affected stream and analyzed for their target heavy metal content and geochemical distribution using ICP-AES/MS and sequential extraction (SQE) methods. Analyses of sediment mineralogy were made by XRD, optical microscopy, FE-SEM/EDS and TEM/EDS. Water chemistry results revealed relatively low metal concentrations of Cu-Co-Mn ranging from below detection limit (bdl) to 60mg/l. SQE analyses show high total target metal concentrations ranging from (1-12000mg/kg) in sediments, which obviously supports the possible adsorption and precipitation processes to be taking place. Low concentrations are as a result of the increasing pH and possible metal adsorption and precipitation on sediment. The target metal contents were highest in exchangeable fraction Cu (100-2500mg/kg), Co (1-50mg/kg), Mn (bdl-2g/kg), and in carbonate fraction Cu (2-500mg/kg), Co (0.5-20mg/kg), Mn (bdl-1.2g/kg) and in amorphous Fe mineral fraction Cu (2-1000mg/kg), Co (1-100mg/kg) and Mn (0.5-2.5g/kg) respectively. The other remaining fractions had very low metal concentrations. FE-SEM/EDS and TEM/EDS techniques showed some metal adsorption phases on biotite and kaolinite confirming the earlier results of SQE. The amorphous Fe mineral determined using SQE reveal an average of between 3.5-12 g/kg. From the surface complexation modeling between amorphous Fe mineral and the metals shows that the range of pH condition, 6.5-7.5 is strongly recommended for better sorbed fraction of Cu-Co-Mn on amorphous Fe mineral. From the above results, it was found that the geochemical partitioning of metals to the most labile exchangeable fraction which easily releases metals to the environment depending on the prevailing conditions (i.e pH) can as well be treated by ion exchange, surface complexation by amorphous Fe mineral and carbonation. The advantages of this treatment method is that heavy metal can easily be recovered from sludge through the application of relatively weak acid and at the same time reducing the sludge volumes through utilization of the sediments as sand for engineering purposes.

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